Glass, Marine Biology & Physics

By Jenna Efrein, Carolyn (Jack) Delli-Santi, and Vivek N. Prakash

Glass and physics, this connection we understand, but why add marine biology? At the University of Miami, interdisciplinary research collaborations are actively encouraged. Through an exploratory contemporary glass working group initiated by the University of Miami Lowe Art Museum's director and curator Dr. Jill Deupi, Jenna Efrein met Dr. Prakash, who runs an organismal biophysics lab, working at the interface of physics, engineering, and biology. The purpose of this glass working group is to explore creative avenues in which glass can integrate into other areas of study and be influenced by it.

The Lowe Art Museum has a large space predominantly dedicated to glass, the Palley Pavilion. Jenna offered anyone from the working group that had yet to see the glass studio to come for a visit. Dr. Prakash came with a project in mind.

He wanted to represent in glass the microscopic marine animal he was studying, the *Trichoplax*.[1] The animal mirrored many of the same qualities of glass; depending on the heat, it can be elastic, ductile, and brittle. As intrigued as Jenna was, she needed two things: 1) a research directive beyond representation, and 2) help. Along came Carolyn Delli-Santi. They were a student with Jenna and were also a double major in marine science and biology. They became what Jenna likes to call a "hybrid" student. Since they knew both areas well, they were able to translate science into accessible language and be the continuity and fact checker throughout the process, as well as the glass fabricator and shop assistant..

The research directive became refined when we applied for and won an internal University grant called U-LINK, as a team led by Dr. Prannoy Suraneni, an assistant professor of civil engineering. The U-LINK grants support teams

Trichoplax adhaerens is one of the "Earth's simplest animals" (Image courtesy of Oliver Voigt/Wikimedia Commons/CC-BY-SA-3.0.)

of scholars from multiple disciplines in collaborative, problem-based inquiry to address complex challenges. The goal of the investigation through glass is to provide valuable scientific insights into marine biology and physics, most specifically animal tissue strain. The purpose of these studies is to investigate the fundamental principles of epithelial tissue integrity and repair.[2] This comprehension aids in tissue recovery in organ transplants and skin grafting. One of the best-suited animals for these studies is the asexual millimeter-scale organism in the Placozoa phylum known as *Trichoplax adhaerens*.[3]

We would build on our biophysical observations of this simple marine animal.[4] Some of our initial questions were:

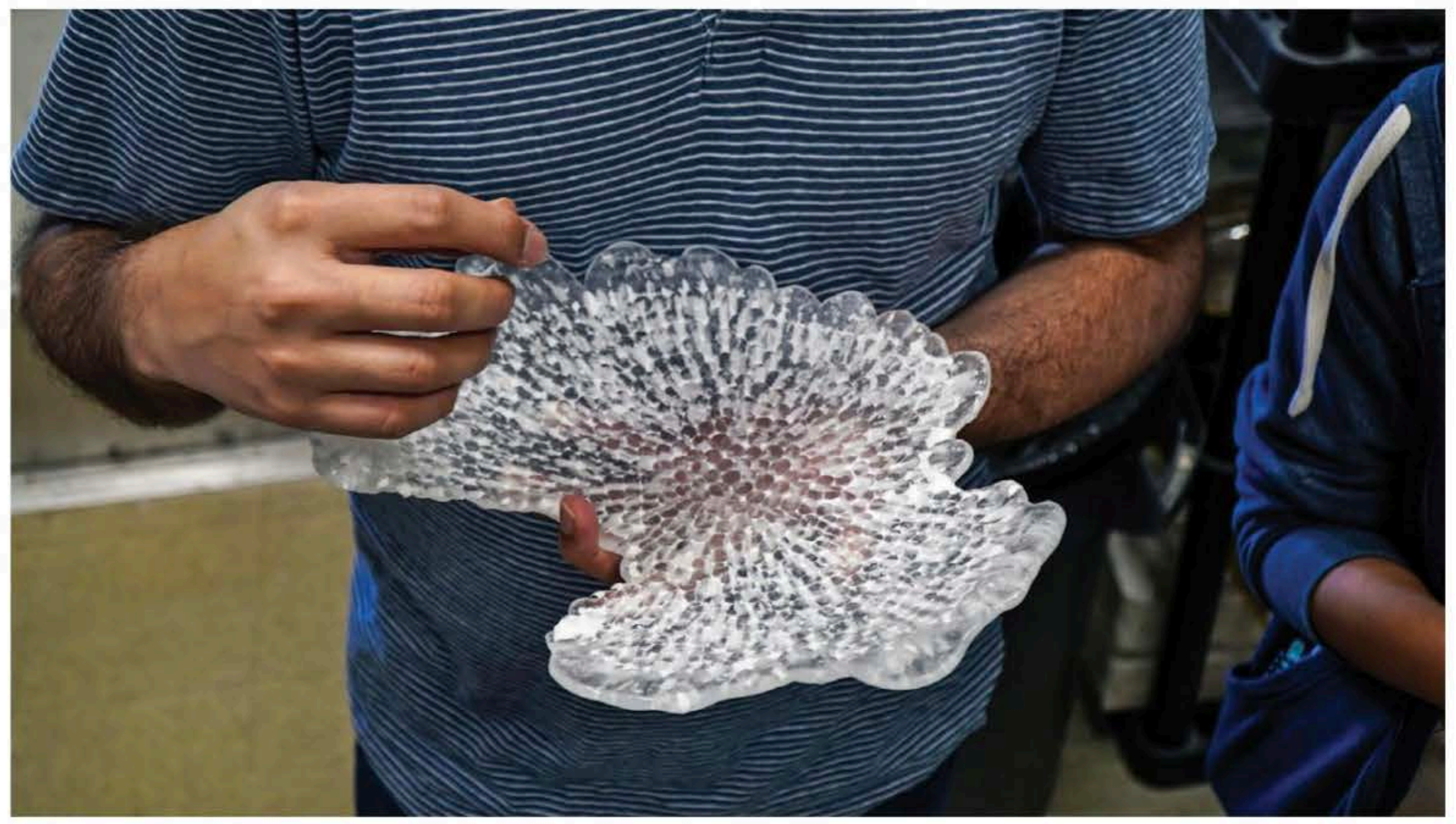
Can glass be used as a material to study tissue strain?

How does physics shape biology?

What are the extreme limits of cell morphology and the results when they go beyond the physical limits?

What are the tissue characteristics and qualities as they change shape and stretch toward and away from their physical limits?

The *Trichoplax's* body plan is composed of three confluent tissue layers, and the upper and lower layers are composed of adjacent, connected cells. On their lower tissue layer, they have cilia, or small hairs, that enable them to move laterally. The upper layer's cells are slightly flatter and larger than those of the bottom layer. The central layer is composed of loose cells sandwiched by the upper and lower layers,

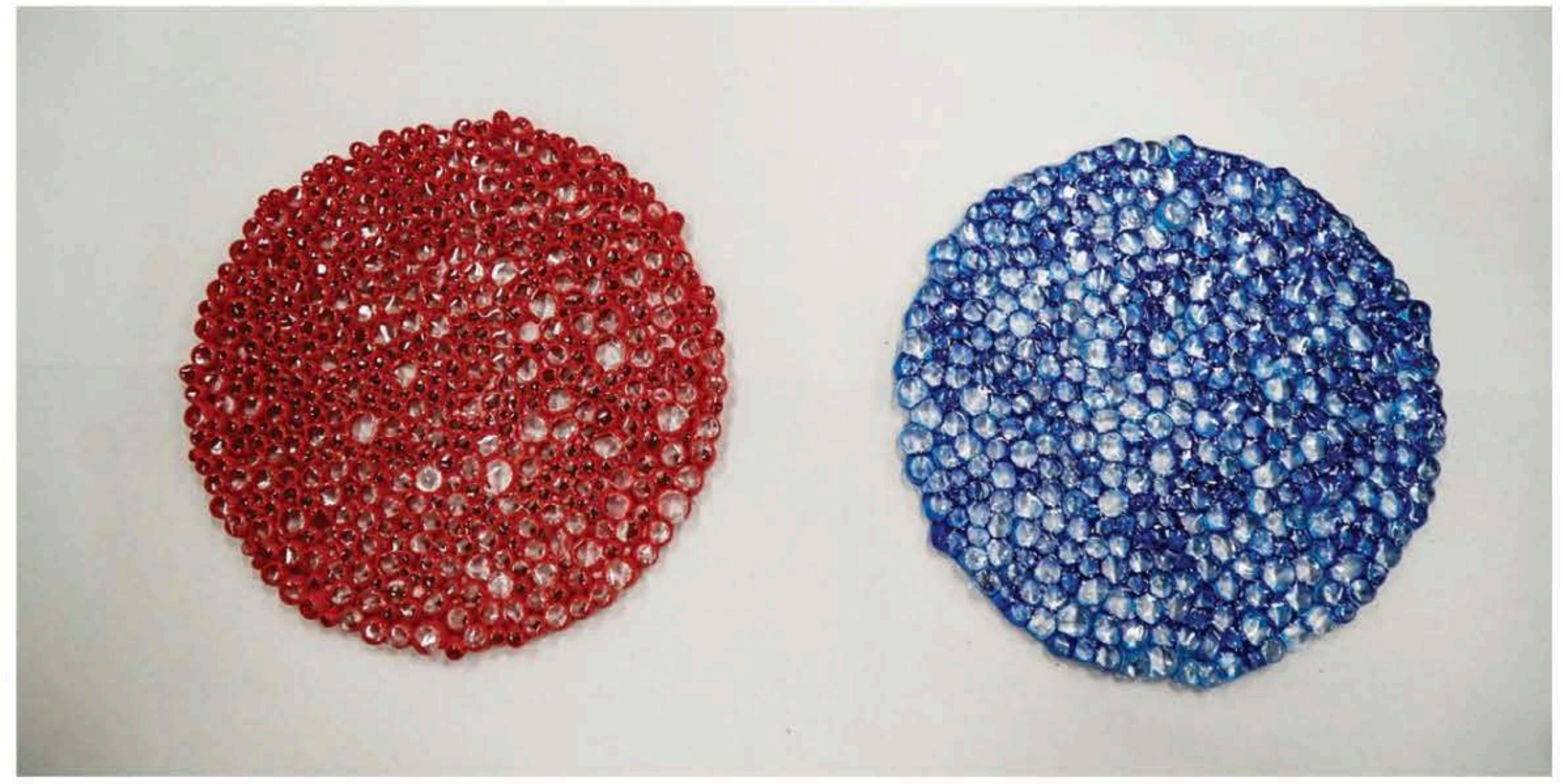


After first bend test on dome

Trichoplax adhaerens single layer of animal cellular structure in simulated animal shape in red veiled cane.

best described as gooey. The animal's tissue properties are exemplified in their physicality. During its elastic state, the animal can stretch and return to its original shape. In its ductile state, the animal can change its shape permanently and start thinning, and at some point, break into two pieces and reproduce asexually. In the brittle state, it will sustain fractures or interior voids that may or may not heal. The tearing of the tissues begins at the lower layer and migrates horizontally first, and then vertically.

To begin our glass model, we needed to replicate their form keeping in mind their base physical properties. We decided to create single layers. The reasoning behind this was to simplify the form to maintain the best possible mimicry of the animal. We experimented with various cellular structures made of clear cane before we finalized our selection of veiled cane. We sampled green and blue for softer cellular walls and red for stiffer cellular walls. These differences would help us model the elastic to brittle qualities while maintaining a core similarity. It also provided a perimeter structure for each cell allowing for measurement post-process. Each cane was cut to approximately 1/4 of an inch in length, stood on end, and fused together allowing for some surface undulation. In the beginning, we shaped it like a sampling of



Top: Disk model versions of Trichoplax adhaerens in red (stiff) and blue (soft glass). Bottom: 8 inch disks on graduated frustums with control disks

an actual animal. Upon further thought and discussion, we shifted to creating circular disks of about eight inches for easier comparative analysis.

Once the single layers were fused, we proceeded with experiments to replicate their movement and cellular deformation. Bending the fused glass seemed to be the most likely comparable to the animal's motility. Relying on gravity as a constant force, we started by bending an organically fused piece on an even plaster-silica convex dome. This yielded the anticipated results of a gradually morphed cellular wall. This aligned with what happens to the *Trichoplax adhaerens* as they move. This is when we decided to reduce the factors on the glass for consistency in testing by shifting to eight-inch circular disks and removing the glass dust from in between the veiled cane walls.

For consistent comparable cellular strain, we augmented the bending structures. Focusing on the physics of similar forms, we increased the pitch at which the glass was being pulled down by gravity. Our new frustums for bending were truncated cones.

Top: Cell measurement before bending. Bottom: Cell measurement post bending.

The team in the glass classroom from left to right: Carolyn (Jack) Delli-Santi (co-presenter), Leah Henseler (future "hybrid student), Jenna Efrein (co-presenter), Vivek Prakash, Gopika Madhu (physics graduate student). Photo credit: Anthony Miles.

They were designed in Rhino, carved on a CNC machine, and then cast in plaster-silica molds. They all had the same upper surface contact of three inches, but their bases increased in width to five, seven, and nine inches respectively. The concept was that the smaller base with the sharper downward pitch would increase the force on the tissues while maintaining the same upper heat temperature and soak time. A reference "control" disk was also included in the firing. About ten random cellular walls were measured before and after the bending process. It was clear in the results that the cellular movement and tissue deformation increased the cell apex area with increasing force.

As glass bent over the frustums, it first accumulated in dense masses along the slopes of the frustums before migrating toward the base, eventually accumulating around the perimeter of the base. Similarly, collective tissue migration begins with cell density rising as neighboring cells restrict the motion of each cell before the dense mass forces the cells to migrate as a group. The glass tissues created here modeled *Trichoplax* properties effectively. By creating cohesive tissues and measuring cell area change before and after entering the transition state, cellular movement and tissue deformation could be observed and quantitatively measured. Combining these promising results with the ability to create precise experimental parameters and the unique ability to arrest and study an experiment at any time step (i.e. through sudden cooling) proves that glass tissues have a promising future in the study of tissue mechanics. This creates unique methodologies and opportunities for investigation that are not feasible in live animal studies, especially just before and at the moment of brittle fractures.

With the knowledge that glass can be used as an analog medium to study the *Trichoplax*, we will develop more specific tests to strain the tissues, recombine, and fracture. As our methods evolve so will the complexity of our models combining the three layers into a single animal. will be designing different strain tests and recording the tissue deformation observed in lateral stretching and epithelial layer healing experiments.

1. Vivek N. Prakash, Matthew S. Bull, and Manu Prakash. "Motility-induced fracture reveals a ductile-to-brittle crossover in a simple animal's epithelia." Nature physics 17, no. 4 (2021): 504-511.
2. Setareh Gooshvar, Gopika Madhu, Melissa Ruszczyk, and Vivek N. Prakash. "Non-bilaterians as Model Systems for Tissue Mechanics." Integrative And Comparative Biology (2023): icad074.
3. Ibid.
4. Prakash, 504-511.
5. Ibid.

LECMO

Experimental Kiln Forming With Recycled Glass

By Morgan Gilbreath

Morgan Gilbreath, What We're Made Of, waste glass collected from various studios, kiln cast and coldworked, 2018. 11" x 9' when stacked.Photo credit: Stephanie Price.

Working with recycled glass can offer many benefits to your studio practice and serve as an endless playground for your ideas. Found glass materials are a sustainable, accessible, and affordable alternative to specialty art glass that is brimming with aesthetic and conceptual potential for artists and institutions alike.

When working with a piece of found or manufactured glass, it is important to assess the glass based on the following considerations:

- *Source:* Where did the glass come from? How was it made and in what quantity? If you know the manufacturer of the glass, you can attempt to contact them for the precise information you are seeking (annealing point, melting point, strain point, etc). Exploring the source can also give you insight into the working properties of the glass and help inform the writing of your kiln program. For example, if you are a furnace worker, think about the differences between blowing with furnace glass versus brown beer bottle glass. Furnace glass has a longer working time, while the brown bottle glass was formulated to get hot really fast (to be blown into factory molds and then rapidly anneal and cool).
- *Compatibility:* Every stable piece of glass should be compatible with itself. When using plate glass, it is best if you can work from one sheet of glass rather than several different ones. When using bottles (with labels and all adhesives removed), note that all manufacturers are different. To help ensure compatibility, I try to use bottles from the same package in hopes that they were produced at a similar time, and therefore have similar COEs. Even with all of these precautions taken, compatibility of found and collected glass is no guarantee. It is a calculated creative risk, but sometimes your kiln failures become your best new discoveries. Although I sometimes encounter compatibility issues, more often than not I am pleasantly surprised at what I'm able to get away with.
- *Devitrification:* Unlike furnace glass and fusible art glass, manufactured glass is not formulated to be re-heated and re-worked. Because of this, devitrification is much more prevalent and harder to control. This factor cannot be avoided entirely; although some surface devitrification may be cold worked away. In my personal work, I love the texture of devitrification and think that it can be utilized as a unique design feature.
- *Particle Size:* What is the format of the glass you will be melting (sheets, bottles, shards, frit, powder, etc.)? The smaller the particle size, the more surface area that will be prone to creating bubbles and/or devitrification in your kiln formed glass. If you are seeking visual clarity in your kiln formed glass, larger pieces, sheets, or blocks of glass would be recommended.
- *Fluxes:* Understand that the more times you heat a piece of glass to melting point, the more the fluxes and additives in the glass will burn out. This can affect the color, workability, devitrification, and even the COE. This will happen at different rates in each glass. Pay attention and take note of any observations.
- *Annealing Point:* If the annealing temperature is unknown, do an annealing test in the kiln; I use Fritz Driesbach's cane-in kiln method as described in Henry Halem's *Glass Notes*. Over time, you will begin to get a sense of each type of glass and its properties. When doing small tests, I estimate the annealing temperature. But when working on a large piece, I will complete several different annealing tests before firing the final object.